Hospital Isolated Power Systems

Class 4800

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GROUPE SCHNEIDER

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OVERVIEW

This bulletin has three purposes:

- To demonstrate to hospitals the need for isolated systems
- To guide the engineer in the application of hospital ungrounded systems
- To describe in detail the Square D equipment used to design effective and economical isolated ungrounded systems

Square D has been building isolating transformers for hospital use since the first equipment standards appeared in 1944. We have built an enviable reputation for reliability, low sound levels, and minimum inherent leakage.

Proof of the engineered superiority of Square D products is found throughout the country in numerous installations, many dating to the earliest applications of isolating transformers.

This bulletin is not intended as a “do it yourself” manual for installation of hospital isolated systems. The information contained here regarding codes and standards is current as of this writing. However, these codes and standards are continually changing and are also subject to local changes and interpretations.

Any hospital considering design changes to electrical systems in critical care patient areas should obtain the services of an electrical consulting engineer. The technical complexities of today’s hospitals dictate that all involved parties have a thorough understanding of the hospital’s objectives. This is the only way to avoid purchasing unnecessary equipment.

Time spent planning the changes will result in large dividends, provided the following parties are involved:

- Consulting engineer
- Hospital administrator
- Hospital engineer
- Chief of surgery
- Chief of anesthesiology
- Cardiologist
- Manufacturer’s representative

HISTORY

During the 1920s and '30s, the number of fires and explosions in operating rooms grew at an alarming rate. Authorities determined that the major causes of these accidents fell into two categories:

- Man-made electricity
- Static electricity (75% of recorded incidents)

In 1939, experts began studying these conditions in an attempt to produce a safety standard. The advent of World War II delayed the study’s results until 1944. At that time, the National Fire Protection Agency (NFPA) published “Safe Practices in Hospital Operating Rooms.”

The early standards were not generally adopted in new hospital construction until 1947. It soon became apparent that these initial standards fell short of providing the necessary guidelines for construction of rooms in which combustible agents would be used.

NFPA appointed a committee to revise the 1944 standards. In 1949, this committee published a new standard, NFPA No. 56, the basis for our current standards.

The National Electrical Code (NEC) of 1959 firmly established the need for ungrounded isolated distribution systems in areas where combustible gases are used.

In the same year, the NEC incorporated the NFPA standards into the code. The NFPA No. 56A–Standard for the Use of Inhalation Anesthetics, received major revisions in 1970, 1971, 1973, and 1978.

In 1982, NFPA No. 56A was incorporated into a new standard, NFPA No. 99—Health Care Facilities. The new document includes the text of several other documents, such as:

- NFPA-3M
- 56K
- 76A
- 76B
- 76
- 56HM
- 56B
- 56C
- 56D
- 56G

The material originally covered by NFPA 56A is now located in Chapter 3 of NFPA No. 99. NFPA No. 99 was updated in 1984, 1987, 1990, 1993 and 1996.

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The increased use of electronic diagnostic and treatment equipment, and the corresponding increase in electrical hazards, has resulted in the use of isolated ungrounded systems in new areas of the hospital since 1971. These new hazards were first recognized in NFPA bulletin No. 76BM, published in 1971. Isolating systems are now commonly used for protection against electrical shock in many areas, among them:

- Intensive care units (ICUs)
- Coronary care units (CCUs)
- Emergency departments
- Special procedure rooms
- Cardiovascular laboratories
- Dialysis units
- Various wet locations

ELECTRICAL HAZARDS IN HOSPITALS

The major contributors to hospital electrical accidents are faulty equipment and wiring. Electrical accidents fall into three categories:

- Fires
- Burns
- Shock

This section covers the subject of electrical shock.

Electrical shock is produced by current, not voltage. It is not the amount of voltage a person is exposed to, but rather the amount of current transmitted through the person's body, that determines the intensity of a shock. The human body acts as a large resistor to current flow. The average adult exhibits a resistance between 100,000 ohms (Ω) and 1,000,000 Ω, measured hand to hand. The resistance depends on the body mass and moisture content.

The threshold of perception for an average adult is 1 milliampere (mA). This amount of current will produce a slight tingling feeling through the fingertips.

Between 10 and 20 mA, the person experiences muscle contractions and finds it more difficult to release his or her hand from an electrode.

An externally applied current of 50 mA causes pain, possibly fainting, and exhaustion.

An increase to 100 mA will cause ventricular fibrillation.

The hazardous levels of current for many patients are amazingly smaller. The most susceptible patient is the one exposed to externalized conductors, diagnostic catheters, or other electric contact to or near the heart.

Surgical techniques bypass the patient's body resistance and expose the patient to electrical current from surrounding equipment. The highest risk is to patients undergoing surgery within the thoracic cavity. Increased use of such equipment as heart monitors, dye injectors, and cardiac catheters increases the threat of electrocution when used within the circulatory system.

Other factors contributing to electrical susceptibility are patients with hypokalemia, acidosis, elevated catecholamine levels, hypoxemia, and the presence of digitalis. Adult patients with cardiac arrhythmias can be electrocuted through the misuse of pacemakers connected directly to the myocardium.

Infants are more susceptible to electric shock because of their smaller mass, and thus lower body resistance. Much has been written about current levels considered lethal for catheterized and surgical patients. Considerable controversy exists about the actual danger level for a patient who has a direct electrical connection to his or her heart. The minimum claimed hazard level seems to be 10 microamperes (μA) with a maximum level given at 180 μA. Whatever the correct level, between 10 and 180 μA, it is still only a fraction of the level that is hazardous to medical attendants serving the patient.

It is believed that approximately 1,000 Ω of resistance lies between the patient's heart and external body parts.

All of this information leads us to the conclusion that the patient environment is a prime target for electrical accidents. Nowhere else can one find these elements: lowered body resistance, more electrical equipment, and conductors such as blood, urine, saline, and water. The combination of these elements presents a challenge to increase electrical safety.

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Leakage Currents

Electric equipment operating in the patient vicinity, even though operating perfectly, may still be hazardous to the patient. This is because every piece of electrical equipment produces a leakage current. The leakage consists of any current, including capacitively coupled current, not intended to be applied to a patient, but which may pass from exposed metal parts of an appliance to ground or to other accessible parts of an appliance.

Normally, this current is shunted around the patient via the ground conductor in the power cord. However, as this current increases, it can become a hazard to the patient.

Isolated systems are now commonly used to protect against electrical shock in many areas, among them:

- Intensive care units (ICUs)
- Coronary care units (CCUs)
- Emergency departments
- Special procedure rooms
- Cardiovascular laboratories
- Dialysis units
- Various wet locations

Without proper use of grounding, leakage currents could reach values of 1,000 µA before the problem is perceived. On the other hand, a leakage current of 10 to 180 µA can injure the patient. Ventricular fibrillation can occur from exposure to this leakage current.

Figure 1 illustrates the origin and path of leakage current.

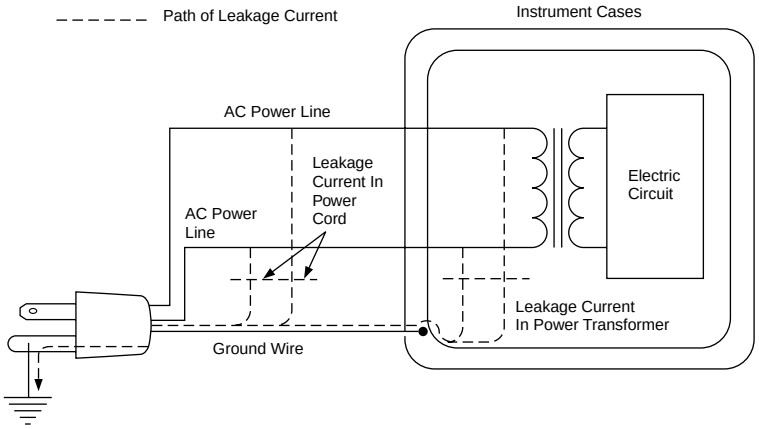

Figure 1 Origin of Leakage Current

Failure to use the grounding conductor in power cords causes a dangerous electrical hazard. This commonly results from using two-prong plugs and receptacles, improper use of adapters, use of two-wire extension cords, and the use of damaged electrical cords or plugs. Figure 2 illustrates these hazards.

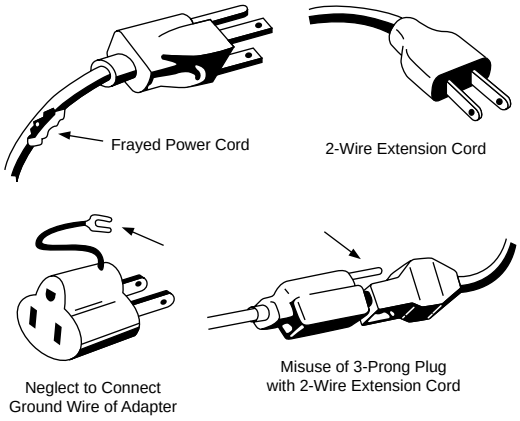
Frayed Power Cord
2-Wire Extension Cord
Neglect to Connect Ground Wire of Adapter
Misuse of 3-Prong Plug with 2-Wire Extension Cord

Figure 2 Electrical Hazards

Answers

There are no perfect electrical systems or infallible equipment to eliminate hospital electrical accidents. However, careful planning on the part of the consulting engineer, architect, contractor, and hospital personnel can reduce electrical hazards to nearly zero. Hospital electrical equipment receives much physical abuse; therefore, it must be properly maintained to provide electrical safety for patients and staff.

Procedures for electrical safety should include the following:

- Check all wall power receptacles and their polarities regularly.
- Routinely verify that conductive surfaces are grounded in all patient areas.
- Request that patient electrical devices such as toothbrushes and shavers be battery powered.
- Use completely sealed and insulated remote controls for use in patient beds.
- Use bedrails made of plastic or covered in insulating material.

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CODES AND STANDARDS

It would not be practical to attempt to reproduce the codes and standards that affect the application of isolated distribution systems in hospitals. As was previously mentioned, codes are continually refined and updated, with frequent amendments between major publications. All hospitals should have copies of the current standards for reference; the design engineer **must** have this information available. Obtain copies of all standards referenced in this bulletin from the National Fire Protection Association, Batterymarch Park, Quincy, MA 02269.

This chapter briefly covers the sections of codes and standards that apply to hospital isolated ungrounded distribution systems. This chapter only covers a few of the important points within these standards. A thorough study of applicable codes and standards is required to effectively design a project.

NFPA No. 99

History

Published by the NFPA, this code is included as a reference in the NEC Article 517.

NFPA No. 99 addresses fire, explosion, and electrical safety in hospitals. It consolidates 12 individual NFPA documents or standards into one document.

Many hospitals and consulting engineers are unaware of this document and its requirements. Square D recommends that all consulting engineers who design hospitals have the hardcover “handbook” version of this document available.

Anesthetizing Location Classifications

The first type of location is that which is flammable because explosive anesthesia is used. This location must be designed to comply with NEC Article 501.

There are many other requirements for the flammable anesthetizing locations; these requirements are discussed in Chapter 12 of NFPA No. 99. Explosive anesthesia is now virtually non-existent in the United States. Therefore, this handbook does not cover the flammable location in any detail.

Non-flammable anesthetizing location requirements are also covered in Chapter 12 of NFPA No. 99. A permanent sign must be displayed at the entrance to all flammable locations. It must state that only non-flammable anesthetics can be used in the room.

Non-flammable anesthetizing locations can be further divided into locations that are subject to becoming wet and those that are not. A wet location requires special protection against electrical shock. The allowable protection is as follows:

- Ground-fault circuit interrupter if first-fault conditions are to be allowed to interrupt power
- Isolated power system if first-fault conditions are not to be allowed to interrupt power

The governing body of the hospital will make the determination of a “wet location,” using the following definition:

> A patient care area that is normally subject to wet conditions while patients are present. This includes standing fluids on the floor or drenching of the work area, either of which condition is intimate to the patient or staff. Routine housekeeping procedures and incidental spillage of liquids do not define a wet location.

NFPA No. 99 defines the items in an anesthetizing location, which must be powered from the isolated ungrounded system. Because this section is subject to individual interpretation by local Code authorities, work closely with these authorities before selecting the equipment to be powered from standard grounded systems. This is especially important when ordering permanently installed equipment, such as X-ray apparatus. NFPA No. 99 and the NEC Article 517 allow the grounded circuit providing power to an isolated system to enter the non-hazardous area of an anesthetizing location. However, ungrounded wiring and grounded service wiring cannot occupy the same conduit or raceway.

The primary and secondary of the isolation transformer cannot exceed 600 volts (V) in any isolation system that supplies power to an anesthetizing area or other critical care patient area. The secondary circuit conductors must be provided with an approved overcurrent protective device in both conductors of each branch circuit.

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Paragraph 3–3.2.2.2 of NFPA No. 99 sets the limits of impedance to ground of the isolated system and the instructions for testing to determine compliance with the standards. The size of the isolation transformer should be limited to 10 kVA or less.

Even in the most sophisticated operating rooms, the equipment load rarely exceeds 5 kVA. When writing specifications, we suggest choosing an isolated transformer rated at 5 kVA, having a continuous overload capability of 25 to 50%. The transformer will thus be designed to operate at a relatively cool normal temperature, but will still be able to handle future demands which exceed today's norm.

Conductors for the isolated ungrounded system must be color-coded:

- Orange for conductor #1
- Brown for conductor #2
- Green for the grounding conductor.
- Where three-phase isolated systems are used, the third color, or that for conductor #3, must be yellow.

Paragraph 3–3.2.2.3 of NFPA No. 99 describes the line isolation monitor (ground detector) required to monitor the isolated system. The limitation for total system hazard is set at 5 mA.

Paragraph 3–3.3.2 of NFPA No. 99 specifies the "Grounding System." This subject is also discussed in detail in "grounding" on page 14 of this handbook.

Article 517, National Electrical Code—NFPA No. 70

Article 517-3 specifies the legal minimum requirements in most states. It is the document used by most inspectors. When designing the system, use it in conjunction with NFPA No. 99, which is included as a reference in Article 517. Other NFPA standards are also referenced in Article 517, such as NFPA-101 and NFPA-20.

Patient Care Areas

Article 517 defines three types of patient care areas:

- **General Care Areas:** patient bedrooms, examining rooms, treatment rooms, clinics, and similar areas. In these areas, the patient may come in contact with ordinary appliances, such as nurse call systems, electrical beds, examining lamps, telephones, and entertainment devices. Patients may also be connected to electro-medical devices, such as heating pads, EKGs, drainage pumps, monitors, otoscopes, ophthalmoscopes, and IV lines.
- **Critical Care Areas:** special care units, intensive care units, coronary care units, angiography laboratories, cardiac catheterization laboratories, delivery rooms, operating rooms, and similar areas. In these areas, patients are subjected to invasive procedures and connected to line-operated, electro-medical devices.
- **Wet Locations:** patient care areas normally subject to wet conditions while patients are present. This includes standing fluids on the floor or drenching of the work area, either of which condition is intimate to the patient or staff. Routine housekeeping procedures and incidental spillage of liquids do not define a wet location. Critical care and general care areas can also be considered wet areas. The governing body of the hospital determines whether a location is to be considered "wet."

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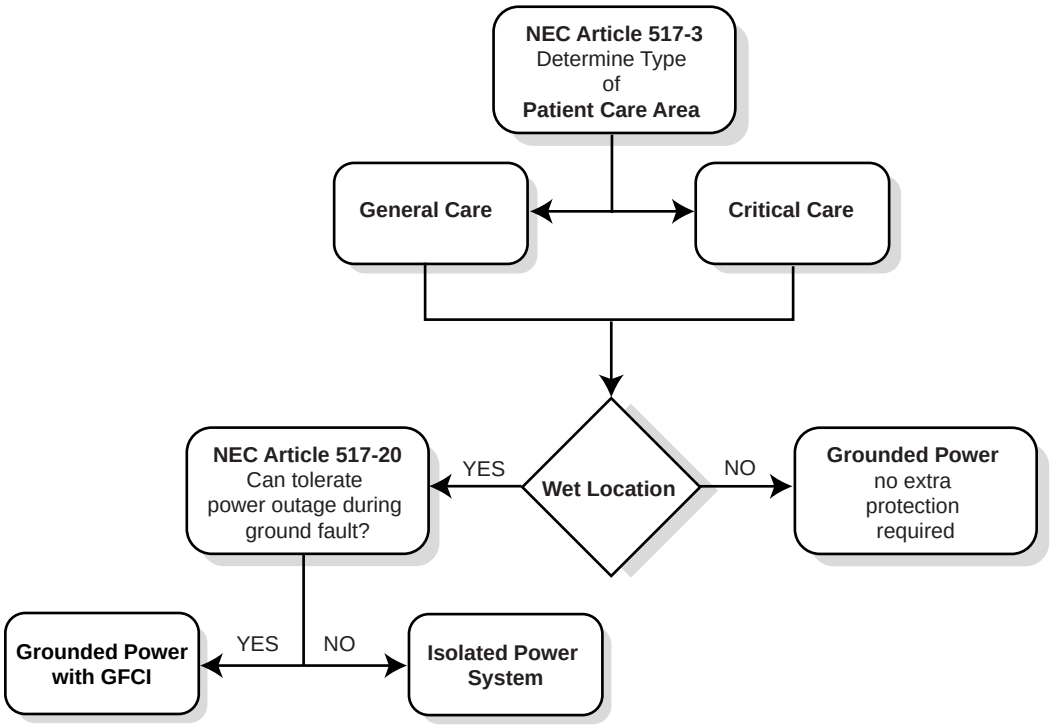
Anesthetizing Location Classifications

As with NFPA No. 99, anesthetizing locations are classified as:

- Hazardous locations which use flammable anesthetics. These locations must meet class I division requirements and must have isolated power systems.
- Other-than-hazardous locations, allowing the use of grounded power systems.

Both types of anesthetizing locations must be further classified as “wet” or “not wet” areas. If designated as a wet location, extra electrical protection is required. The acceptable protection is the same as that defined for NFPA No. 99.

The designation of all of the above-mentioned areas in the health care facility is the responsibility of the facility’s governing body. Before a designer can choose the proper electrical distribution system for a hospital, the governing body of the hospital must inform the designer about the location’s use. This requires close coordination with the medical staff of the facility, to ensure that the designer understands current medical procedures as well as possible future procedures.



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The NEC recognizes that hospital patients are more susceptible to electrical shock than are normally healthy individuals. Consequently, patients must be protected through use of special procedures. The special procedures and equipment required become more complicated with the degree of electrical susceptibility of the patient.

The hospital administration and designer are responsible for determining the degree of patient susceptibility and selecting the correct equipment. This selection process requires close communication between the hospital administration, medical staff, and the consulting electrical engineer.

It is generally accepted that any time the normal body resistance of a patient is bypassed, the body becomes electrically susceptible. Degree of susceptibility varies from having an electrical probe or catheter connected to the heart muscle, to having electrodes attached to the outer skin after conductive paste is applied. Patients who are anesthetized, or are demobilized through illness, restraints, or drug therapy, also have a higher degree of electrical susceptibility than normal individuals. Such patients cannot avoid or disconnect themselves from an electrical hazard that would be relatively harmless to a normal person.

For example, a patient who has impaired nerve sensitivity cannot detect heat. A cup of very hot coffee would not be a hazard for a normal person; however, it is a potential disaster for the nerve-impaired individual.

Certain medical conditions may render a patient particularly vulnerable to electrical shock. These patients may require special protection even though their normal body resistance has not been intentionally bypassed.

Give special consideration to the following potential electrically susceptible patient areas:

- Acute care beds
- Angiographic labs
- Cardiac catheterization labs
- Coronary care units
- Delivery rooms
- Dialysis units
- Emergency room treatment areas
- Human physiology labs
- Intensive care units
- Operating rooms
- Post-operative recovery rooms

UL 2601-1

This is the UL Standard against which all medical and dental equipment is tested by the Underwriters' Laboratories. UL derives its standards for performance requirements from the applicable NFPA standards and the NEC. Demand that any appliance purchased for use in patient care areas be labelled under this UL Standard for use in the specific area designated.

UL 1022

Line isolation monitors are measured against this UL Standard. Insist that any line isolation monitor installed in the facility have a UL component recognition under this standard.

UL 1047

This is the UL Standard for hospital isolating equipment. Do not accept any hospital isolation equipment unless it is listed and labelled as a complete system under this standard. This assures the hospital and consulting engineer that the equipment meets all existing codes and standards.

ISOLATED SYSTEMS

The term "isolated system" can apply to many systems in a hospital, such as the management of patients having a communicable disease. However, it is unlikely that any of the other systems is as widely used, yet as poorly understood, as the system discussed in this handbook.

The isolating system covered in this manual is really an "isolated ungrounded electrical distribution system." Although these isolated systems are very important to hospital operations, many hospital staff lack even a basic understanding of how isolating systems work. This includes the technicians responsible for maintaining the systems.

Consulting engineers and plant operating engineers who specify and apply these isolating systems usually understand them; but they have difficulty passing this knowledge to laymen. Hopefully, this section will help them fill this communication gap. The following simple analogy should help the layman understand isolated systems.

In this example, consider an electrical receptacle in the counter area of a household kitchen. The

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ground in this case is the kitchen plumbing fixture. Figure 3 illustrates this example.

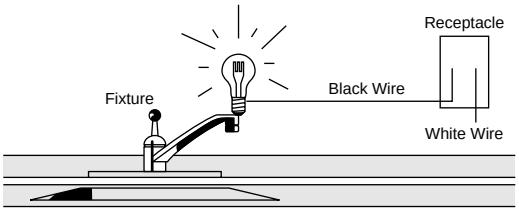

Figure 3 Kitchen Plumbing As a Ground

Electrical current comes to the receptacle via two insulated conductors. One of them is usually black, the other white. Many people feel they can safely touch either one of these conductors, but this oversimplification could result in a dangerous shock.

When the two conductors touch each other, a violent arc results, part of the conductor melts, and the fuse opens or the circuit breaker trips. This demonstrates the energy that is used when any household appliance is run. Because the household appliance does not open a fuse or trip a circuit breaker the appliance places resistance between the two conductors. In placing resistance, the appliance limits the amount of current that can flow. However, the amount of current that can flow must always be less than the current rating of the fuse or circuit breaker.

When a light bulb touches both wires, it illuminates. If one of its terminals touches the white conductor in the receptacle, nothing happens. If the other terminal of the light bulb touches the kitchen plumbing, nothing happens. If the white wire touches the plumbing, nothing happens. The conclusion must be that the white wire is safe to handle as long as the black conductor is not handled at the same time.

Using the example as above, but with the black wire, the connections cause different results. When one terminal of the light bulb touches the black conductor, nothing happens. However, when the other terminal of the light bulb touches the kitchen plumbing, the bulb illuminates as it did when it touched both wires. When the black wire touches the kitchen plumbing, there is a violent arc, much as if both conductors had touched each other.

The conclusion from the above paragraph is that it is safe to handle the black conductor only if you do not simultaneously touch the white conductor, kitchen plumbing, or any other grounded item.

Obviously, the white conductor and the kitchen plumbing have something in common. That is that they are *grounded*. A wire becomes grounded when it is attached to a copper rod driven into the ground or to a convenient piece of conductive plumbing pipe, which ultimately runs into the ground. The white conductor (known as the *neutral*) is grounded when it is installed by the utility company.

The conclusion from the previous paragraph is that current flows from the black wire to *any* grounded conductive surface, of which there are many. The black conductor is safe to handle as long as you do not simultaneously touch the white conductor or any grounded item.

This type of electrical system is commonly called a “grounded electrical distribution system.”

Ungrounded System

To convert available power from a receptacle into an *ungrounded service* is possible. The first step is to *isolate* the receptacle from the grounded service. There are several ways to isolate power, but the most common and economical is to use an isolating transformer.

The available grounded electrical power energizes a coil in the isolating transformer; this coil is called the *primary winding*. This induces a current in the *secondary winding*, which is completely insulated from the primary winding by electromagnetic induction. No direct electrical connection exists between the primary and secondary coils.

Figure 4 shows how a transformer is constructed and connected to a receptacle.

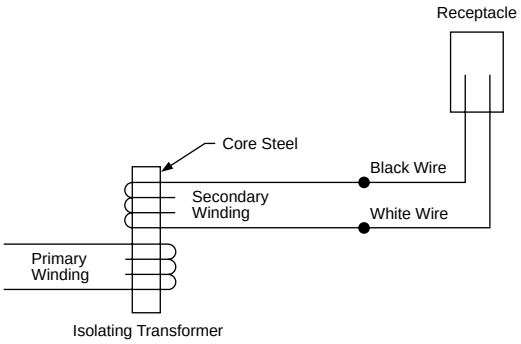

Figure 4 Transformer Construction

When electrical devices are connected across two conductors on the transformer, they work as if they were connected directly to a grounded system. The conclusion to be drawn is that the isolating transformer provides the same usable electrical energy as does the grounded power circuit.

Repeating the experiments with the light bulb, we find that current will not flow if a single terminal of

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the light touches either secondary conductor of the isolating transformer. No current flows if either secondary conductor of the transformer touches the plumbing (ground). Furthermore, no sparking occurs when either conductor touches the plumbing; the fuse or circuit breaker maintains the connection.

The conclusion is that current does not flow from either conductor of the isolated system to ground. In more technical terms, **no hazardous potential to ground exists from either conductor of an isolated electrical system.**

System Comparison

The previous section illustrates that conductors of an isolated system are safer to handle than are the conductors of a grounded system. Now let's use the same kitchen receptacle to show a comparison between a grounded system and an isolated system.

When installing a new curtain rod at the window over the kitchen sink, one would probably use a small electric drill. If the residence was built within the last 30 years, the receptacle most likely has three openings, not two. The third opening is shaped to receive a pin (U slot) rather than a blade-shaped prong. The portable electric drill probably has a three-prong plug. This third point of contact simply connects the metal case of the drill to ground. The connection to ground from the pin on the receptacle is often made by a third wire that is run with the power conductors, or by a metal pipe (conduit) which encloses the two conductors that serve the receptacle.

The electric drill has an electric motor which is completely enclosed in a conductive housing. The housing is connected to a third wire in the power cord, which in turn connects to ground.

The electrical portion of the motor must be completely insulated from the conductive enclosure. If it were not, arcing would result when the black conductor of the grounded system touched the plumbing. This "short circuit" would disengage the circuit breaker or blow the fuse as it did when the live conductor touched the plumbing.

Consider this scenario: the person using the drill touches his or her opposite hand on the plumbing fixture for support. If the drill is in good repair and the enclosure is properly grounded through the power plug, the procedure is safe.

However, what if the insulation around the drill motor is defective, allowing the live conductor of the grounded system to contact the metal enclosure? This is a dangerous situation. If the ground wire is properly attached to the enclosure and connected to ground through the ground pin in the plug, there will be arcing in the drill where it contacts the conductive enclosure. If there is good contact between the live conductor and grounded enclosure, sufficient current will flow to disengage the circuit breaker or blow the fuse.

Two paths to ground are possible, one down the ground wire in the cord into the receptacle ground, and one through the person holding the drill (who is grounded through the plumbing). Since the resistance through the human body is much higher than the resistance through a properly connected ground wire, most of the current follows the path of least resistance (the ground wire); the person holding the drill is safe.

The key to keeping the drill safe is in the ground connection from the drill enclosure to the ground at the receptacle. If this connection is broken (for example, if an improperly connected adapter is used), the only path for current in the enclosure to go to ground is through the drill user. A hazardous level of current could be maintained since the human body has sufficient resistance to keep the current below the level required to disengage the circuit breaker or blow the fuse. The level of current would be high enough to be deadly.

If, on the other hand, the drill is powered from an isolated circuit, and the ground from the drill enclosure is disconnected, there is little potential for current to flow through the drill user. Even if the ground is intact, not enough current flows to disengage the circuit breaker or blow the fuse.

This is a very important factor: if the drill was really a piece of life support equipment, such as a respirator, it would continue to run without disengaging the circuit breaker or blowing the fuse.

Imperfect Isolating

In the previous examples, we assumed a perfect system. Unfortunately, a perfect system is impossible to attain.

Returning to the example of the isolating transformer, we can convert the isolated system back to a grounded system easily, by connecting one secondary conductor of the transformer to ground. This would create the potential for current to flow from the opposite conductor to ground, as it would in any grounded electrical distribution system.

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An isolated system can be unintentionally grounded. For example, if the drill is plugged into the system with the ground intact and there is a fault in the drill to the grounded enclosure, that single fault converts the entire system into a grounded system.

Keep in mind no perfect insulators exist either. What we commonly call “insulators,” such as rubber or plastic coverings on wire, are actually just poor conductors. All materials conduct electricity to some degree. Thus, everything attached to the secondary conductors of an isolating transformer will partially ground the system. Examples of items that partially ground the system, without making direct connection to ground, include the following:

- Insulated wires enclosed in grounded metal conduit
- Electrical components within permanently installed electrical equipment
- Electrical components within portable devices housed in grounded enclosures (commonly referred to as the capacitance of the system)

Because an isolated system can easily become grounded without giving any indication to the user, a way must be found to monitor the integrity of the isolation in the system. With this monitoring, there must be some warning when the system becomes grounded. When the system becomes partially grounded, the warning is still necessary, but a limit must be set for the warning to be sounded. Limits are established by codes and standards, specifically the NEC.

See the “Codes and Standards” page 6 of this manual for additional information. Codes and standards state that an alarm must sound and display (it must be audible **and** visible). The alarm must activate when the integrity of an isolated ungrounded system degrades to the extent that 5 mA of current will flow from either secondary conductor to ground through a zero impedance fault.

Line Isolation Monitor (LIM)

Codes and standards not only specify the limits within which an isolated ungrounded system must operate, but also the method for checking system integrity. A LIM is required to continuously check the resistance (impedance) of the total isolated ungrounded system to ground. The LIM must respond audibly and visibly when the impedance of the system degrades to the extent that 5 mA of current will flow through either conductor of the system to ground in a zero impedance fault.

Several points should be considered:

1. The alarm condition does **not** mean that there is imminent danger to the patient or anyone else. The alarm simply indicates that the system has reverted to a grounded or partially grounded system, which is the same system contained in the rest of the hospital. Correct the problem as soon as possible; but do not interrupt procedures that are being conducted when the alarm sounds.
2. The LIM does not interrupt electrical service. Loss of integrity in the ungrounded system does not affect the operation of life support devices.
3. An activated alarm does not mean hazardous current is flowing. The LIM is a predictive device; by sounding an alarm, it predicts that 5 mA of current could flow from one conductor of the isolated system to ground if a path for that current is provided. This requires that a **second** fault or electric failure must be present in the system before a true hazardous condition exists.

The LIM is equipped with a meter (also required by code) that gives continuous indication of the system’s condition. The meter is calibrated in milliamperes (mA) of current. Its position indicates how much current could flow from either conductor of the isolated system to ground if a path was provided.

NOTE: Keep in mind that this meter merely predicts the possibility of the condition; it does not indicate that current is actually flowing.

Types of LIMs

Several types of line isolation monitors are available. Reviewing them not only helps determine requirements for a system, but helps identify the equipment currently used in the hospital.

Ground Detector. The first unit is not actually a LIM, but rather the original “ground detector,” which is essentially a balanced bridge device. Ground detectors were standard equipment until about 1970, so many of these units are still in use. Inexpensive to build and reliable because of its simplicity, the ground detector is unaffected by and does not create any radio frequency (RF) interference. However, it only recognizes unbalanced resistive or capacitive faults; it cannot recognize a partially grounded system. This

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inability to sound an alarm (to recognized balanced fault systems) is the main reason codes and standards no longer allow its use.

Systems in the field have been observed to allow as much as 30 mA (30,000 µA) to flow from line to ground without sounding an alarm. This very hazardous condition can cause an electrical hazard to the patient or medical staff.

Ground detectors may still be used if they were installed before 1971. Even though not required by code, hospitals should consider revising these systems to match current standards.

Dynamic Ground Detector. The first dynamic ground detectors, now called line isolation monitors, were developed in Canada. They are called dynamic ground detectors, as opposed to static ground detectors, because the measuring circuit continually switches between the two isolated conductors and ground. In this way, it overcomes the greatest inadequacy of static ground detectors — the inability to recognize and sound an alarm at the occurrence of an excessive balanced fault condition.

Although this unit meets current codes and standards, it has two undesirable features:

1. This type of LIM connects to ground through a high resistance so that it can measure the impedance of the total system. This reduces the integrity of the isolated system by partially grounding it. With nothing connected to the system except the LIM, 1000 µA could flow from either line of the isolated system to ground. If the LIM is calibrated to sound an alarm when 2000 µA flow from either line to ground, approximately one-half of the capacity of the total system would be dedicated to the LIM. This limits the amount of equipment that can be connected to an isolated system, often requiring two systems in an operating room, rather than one.
2. Switching between the isolated conductors and ground causes interference on the isolated system. Sometimes, this interference can be detected on patient monitoring equipment, creating difficulty in gathering information needed by the medical staff. In extreme cases, it becomes impossible to use equipment such as an EEG without disconnecting the LIM.

The extent of difficulty encountered with these types of interference varies with the installation and design of the patient monitoring equipment.

The Square D type EDD line isolation monitor is typical of the second generation of LIMs. This unit was the first of the low leakage LIMs. It contributes less leakage to the system because of its higher impedance connection ground. Rather than use half the system capacity for the LIM, this unit reduces LIM contribution to less than 25% of the system's capacity.

The type EDD LIM still uses a switching circuit and still causes interference with patient monitoring equipment.

IGD ISO-GARD® Line Isolation Monitor. This LIM represents the most recent generation of line isolation monitors. It virtually eliminates all of the undesirable features in the early dynamic ground detectors and line isolation monitors. It contributes only 50 µA of leakage to the system, about one percent of the system's usable capacity.

The special circuitry developed by Square D monitors both sides of the line continuously, eliminating the need for switching. It does not generate any interference that could affect patient monitoring devices. For detailed information on the ISO-GARD LIM, see page 51 of this handbook or request the Square D bulletin covering line isolation monitors.

Figure 5 compares the degree of interference produced by the ISO-GARD LIM with older LIMs.

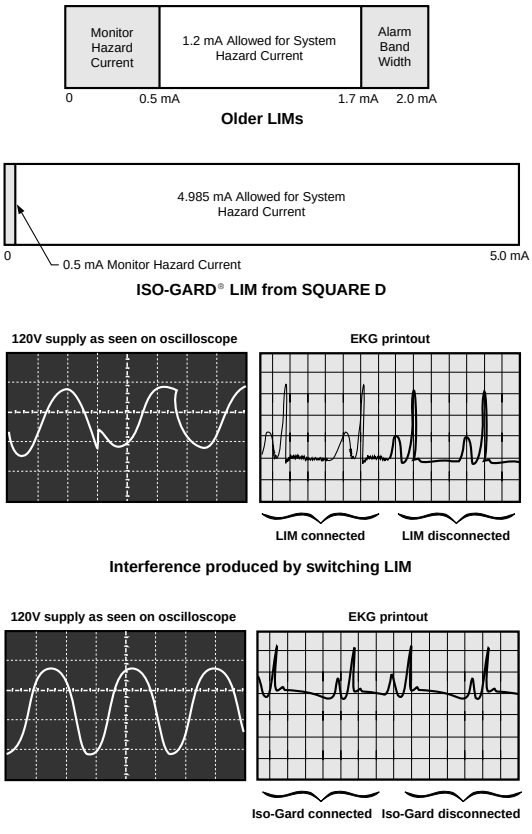

Figure 5

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GROUNDING

Grounding in a patient care or anesthetizing location is an important safeguard against shock and electrocution. Proper grounding dissipates static charges and shunts fault currents and normal leakage currents away from attendants.

Electric Equipment Power Cord Grounding

The green grounding conductor in an equipment power cord prevents static potentials from reaching dangerous values on noncurrent carrying parts such as housings, cases, and boxes of electrical appliances. If these parts are not properly grounded, a static charge could accumulate; the charge could reach a large enough value to automatically discharge as an electric static spark. This static charge could be a hazard to the patient and attendant if it ignited some flammable gas or material, or if it discharged to the patient as a shock.

This grounding conductor also provides a path for leakage current which could be conducted to an electrical appliance case. The magnitude of this leakage current depends on the characteristics of the appliance and its insulation. The leakage current could result in potential differences between pieces of equipment and could flow through vital organs of the patient, if a patient current path is established. For example, during cardiac catheterization, small amounts of current could cause ventricular fibrillation.

Figure 6 illustrates the current path for leakage current which could develop in an electrically operated patient bed. Since the patient provides a grounding path via the attendant and pacemaker, a current divider will result. However, the resistance through the power cord ground conductor is significantly lower, providing protection for the patient. However, if the ground wire is broken, most of the current would flow through the patient. In this example, we assume that non-isolated patient monitoring leads are used.

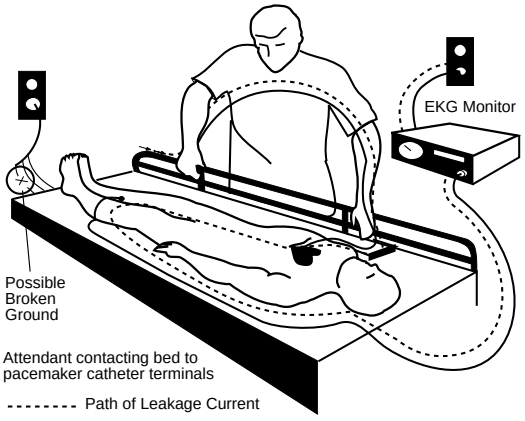

Figure 6

Because the resistance of a grounding conductor is extremely important, you must give it careful consideration. Wire resistance is inversely proportional to its cross-sectional area. The cross-sectional area is usually expressed in units of AWG (American Wire Gauge). The lower the AWG, the larger the wire. For example, the grounding conductor in a power cord is #18 AWG; it represents about 0.0064 ohms/foot. On the other hand, #10 AWG only represents 0.001 ohms/foot.

Current codes and standards for new construction of critical care areas require that no more than 40 millivolts (mV) exist between the reference point and exposed conductor surfaces in the patient's vicinity. This means, for a piece of electrical equipment using a #18 AWG ground wire in a 15-ft power cord, no more than 416 mA of fault current could develop without exceeding the 40 mV potential difference requirement.

These faults could develop through internal aborted components or poor power cord insulation. There is no certain way to prevent these faults; however, their magnitudes can be kept to a minimum through the use of an isolated power system. Using the isolated system, an initial line to ground fault can be kept as low as 5 mA, if the system is operating in the "safe" condition. The power cord ground wire could easily accommodate a 5 mA fault and stay well within the requirements of NFPA No. 99 and the NEC.

Permanently Installed Ground System (Hard Wiring)

Providing proper grounding for all electrical devices assumes that they connect to a sufficient ground system which interconnects to provide an equipotential ground plane for the patient. Current codes and standards require that all conductive surfaces within the patient vicinity must be properly grounded. The grounding system permits intermingling of electric appliances located near or applied to the patient without the hazard of leakage or fault current to the patient. By interconnecting all metal surfaces within the patient area, potential differences between the metal surfaces can be kept to a minimum.

Since a potential difference is required to produce a current flow, the entire ground plane can rise above ground zero as long as all metal is at the same potential. Even if a person contacts two pieces of metal, both at 10V, a current path will not develop. This ground plane is established by the use of a properly connected ground system.

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Equipotential Grounding

The NEC (1971, 1975, and 1978 editions) specified and dictated the use of an equipotential grounding system with maximum resistance for each branch of such a system. While these requirements are considerably reduced in the NEC and NFPA No. 99, grounding requirements still remain more demanding than those shown in Article 250 for other occupancies. Because of this, electrical design engineers should still plan for special grounding requirements in these areas. Carefully study the code to determine exactly what special grounding provisions must be provided in each project.

Ground Jacks

In previous codes, provisions for grounding conductive non-electrical devices were dictated. These provisions were met by supplying each critical patient care area with a specified type of ground jack. Each operating room was required to have a minimum of six ground jacks.

While this is no longer a code requirement, Square D recommends that at least one ground jack be placed in each critical care patient area. This ground jack provides connection to the grounding system for redundant grounding of exceptionally hazardous equipment. The jack also allows connection to the grounding system for testing. The cost of a single ground jack, or even several ground jacks, in a room is quite low.

I. System Concept

With the increased complexity of isolated systems, it is more important than ever to use a system approach in which all components work with each other to obtain a specific result. The components in an isolated power system can be purchased separately; however, it is much easier and makes more sense to purchase a complete system.

When manufacturers design and build complete systems, many factors are considered: proper and attractive packaging, convenient design, and ease of maintenance. The component system, on the other hand, invariably results in duplication of functions, high jobsite labor costs, excessive system leakages, and the lack of a dependable single vendor.

The variety of Square D modular system components gives the electrical consulting engineer and architect great design latitude. Consequently, a system to fit the special needs of each hospital is practical.

In spite of this great versatility, all Square D modules interface with each other perfectly. When designing the modules that make up its systems, the Square D engineering department considered every important requirement for isolated systems. Among these considerations are:

- Operating and panel face temperatures
- Sound levels
- Minimum leakage
- Ease of maintenance
- Interchangeability of components
- Pleasing appearance
- Ease of installation

II. Application

The design of isolated systems from Square D ensures that all pieces of a system are compatible with each other. This is the first step toward having a working system, but it is only one of four ingredients that make up a superior system. The second ingredient has been discussed but bears repeating: there must be good communication between the parties planning the system for the hospital. Poor communication causes poor planning, which will be very costly and time-consuming if the system must be modified after it is installed.

The consulting electrical engineer must be the nucleus of the team that makes the decisions. However, each team member contributes vital information to the system design.

In the past, projects run by capable consulting electrical engineers have required modifications costing several thousand dollars per operating room. This was not because of poor planning, but because the engineers did not receive the information needed to plan usable systems. This lack of information led to such errors as incorrect voltage for portable X-ray machines, insufficient receptacles, and insufficient capacity in isolating systems.

The team approach benefits all members of the hospital team, for example:

- The architect can make the proper provisions for mounting the equipment; this results in superior aesthetic quality. The architect can also specify the proper equipment, avoiding later difficulties.

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- As part of the team, the hospital administrator can make informed decisions when ordering equipment for the operating room, specifying maximum leakages, and correct cords and connectors. The proper accessories are often available at no extra cost, if they are specified when the order is placed.
- The chief staff surgeon can specify a traffic flow within the operating room, allowing the engineer to provide proper receptacle placement.
- If included in the team, the hospital maintenance engineer will better understand the isolated system. This enables the engineer to perform maintenance more conveniently and efficiently.

III. General Application Criteria

A. System Size

The system must stay as small as possible to limit leakage currents. Remember that everything connected to the isolated system increases the total hazard index: LIM, transformer, circuit breakers, secondary wiring, and any peripheral equipment. The system hazard current must be kept well below maximum to allow for normal current leakage, which will come from the equipment operating on this power supply.

Additionally, the code states that the unloaded system, with the LIM disconnected, must have a minimum line-to-ground impedance of 200,000 Ω. On a 120V system, this corresponds to 600 µA when measured through a milliammeter connected between line and ground.

When considering system size, we must include all wiring between the circuit breakers in the isolated panel and their receptacles. *Every foot of wire* contributes leakage, so we must keep the total footage to a *minimum*. This emphasizes the need to place the isolation panel as close as possible to the point of usage.

The use of a central system, containing individual distribution systems for several operating rooms or CCUs, is not practical except in rare circumstances. The only time a central system makes sense is when this location coincides with the closest placement of individual panels to each room. In other cases, the central system would result in longer runs from the panel to the receptacles and devices. This would increase system hazard current.

B. System Capacity

In selecting the capacity of an isolating transformer, remember that the patient care areas generally present an intermittent load condition and load diversity. A given area may contain equipment that requires power greater than the isolated system provides; but the hospital will not use every piece of equipment at the same time.

The isolated power requirement of the operating room is almost always under 5 kVA. However, the Square D 5 kVA isolation panel incorporates a transformer built with a 220°C insulation system, suitable for 150°C rise. The full load design temperature, however, is limited to a 55°C rise. Therefore, the transformer can easily provide power for loads up to 150% of its rating. This is an important feature in an isolating transformer since it provides for intermittent heavy loads, like those presented by hypothermia equipment. In critical care areas, where one transformer serves one bed, a 3 kVA transformer is recommended.

Since the amount of wire is often proportional to the number of circuit breakers, keep the number of circuit breakers to a minimum. This can be done by connecting two to four receptacles to one circuit breaker. In most cases, an operating room panel with eight or ten secondary breakers is sufficient. If additional receptacles are required, up to 16 secondary breakers can be used. Isolation panels serving a single bed in a critical care area require only eight secondary breakers.

C. System Wiring and Conduit

The selection of a proper conductor is one of the most important design criteria of an isolated power system. If improper conductor insulation is chosen, the result is the same as if the capacitive leakage is raised. A good commercially available wire insulation for this application is cross-linked polyethylene, having a mineral filler instead of a carbon black filler. A minimum wall thickness of 2/64" should be demanded for use in 120V, 208V, and 240V applications. It is also important to specify wire with a dielectric constant of 3.5 or less, as recommended by the NEC and NFPA No. 99.

Standard Type THHN wire is definitely unsuitable. It can, however, be used for the ground conductor. The code demands that the #1 conductor in the system be color-coded orange, the #2 conductor color-coded brown, and the ground conductor color-coded green. In three-phase systems, the third conductor shall be color-coded yellow.

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Square D is often asked to specify manufacturers and wire catalog numbers for the low leakage conductor. This is extremely difficult to do since the availability of these wires differs from region to region. Also, manufacturers have sometimes discontinued production of wire types that we have recommended. The most accessible XLP wire has been Rome Cable Corporation low leakage wire #FR-XLP (VW-1 XHHW-2).

Avoid the use of wire pulling compound since it increases the capacitive coupling. The code no longer allows wire pulling compound to be used in conduits for isolated power systems. This compound is usually unnecessary, because most of the runs on an isolated system are short. Occasionally, difficulty occurs in X-ray circuits since these conductors are somewhat larger. These difficult runs can be anticipated and provided for by using oversized conduits to ease the situation.

Obviously, conduits must be dry or the leakage characteristics designed into the system will suffer. During construction, keep conduit ends capped so they remain free from moisture. The specifications should state that, if moisture accidentally enters the conduits, they must be swabbed and thoroughly dried before conductors are pulled. Use minimum fills for conduits; this results in a better random lay of the conductors within the conduit, which further reduces the capacitive coupling.

The table below shows the approximate expected hazard currents per foot of power conductor, using the various wiring schemes described in the preceding paragraphs.The consulting engineer can use this table to estimate the system hazard current at the design stages. Values given are approximate; variations in humidity, conduit moisture content, conduit fill, and wire insulation will give different results.

Hazard Current Leakage Contributed by Wiring

Materials Used	Result
TW wire, metal conduit. Wire pulling compound with ground conductor.	3 µA per ft of wire
XLP wire, metal conduit. No wire pulling compound with ground conductor.	1 µA per ft of wire

IV. System Design

A. Operating Room Layout

Before the electrical design of an operating room begins, some important information should be acquired from hospital personnel. Most hospital operating rooms have a set traffic pattern and positioning for the operating room table. This is usually restricted to the location of the overhead operating room light. However, since the position of the head of the operating room table can be varied, the hospital personnel should advise the electrical engineer of the table's standard position. The traffic pattern, along with the positioning of the surgeon and support team, should also be verified. The positioning of the electrical equipment in the operating room has a direct relationship to this information. In the following example, we will use a configuration shown in Figure 7 on page 18.

The panel is located behind the support team, near the head of the operating room table. The location of this panel is important; correct placement will keep electrical and ground cords out of the traffic area.

A 5 kVA isolation panel is recommended for operating room use. Be sure to determine the load of secondary equipment being used; very few cases will require a 7.5 kVA transformer. The 5 kVA isolation transformer from Square D is capable of a 150% continuous overload within its maximum designed temperature.

Ten secondary circuit breakers are recommended for the panel in this example. Each circuit breaker should supply two power receptacles; 16 receptacles are shown in this illustration. The table below shows the recommended breaker-to-load schedule.

Secondary Circuit Breaker Schedule

Number of Breakers	Load
4	8 Receptacles In Panel (2 Per Breaker)
2	4 Receptacles In Anesthetist's Module (2 Per Breaker)
2	4 Receptacles in Surgeon's Module (2 Per Breaker)
1	Surgical Light
1	Clocks, Film Illuminator

Two additional circuit breakers should be used for the overhead operating room light, the surgical chronometer, and film illuminator. If the optional remote power and ground module is used, the four receptacles in the optional module should be served by one circuit breaker, and the four receptacles in the surgeon's module by another circuit breaker.

When laying out the operating room electrical system, the location of power and ground receptacles is significant. Power and ground cords can be dangerous to circulating personnel; so, whenever possible, locate receptacles so cords do not lie within the major traffic area. Since the operating room support team uses most of the electrical outlets, the majority of the services should be placed behind them, near the head of the table.

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Little traffic occurs between the support team and the anesthetist. Locate a power and ground module at the head of the table so the anesthetist can easily connect equipment.

Locate an additional module behind the surgeon, near the head of the table. This gives the surgeon easy access to power for surgical equipment.

Proper location of the receptacles on these two panels, plus receptacles in the isolation panel, should eliminate tripping hazards in the traffic flow area.

There are distinct advantages to integrating power ground receptacles into one enclosure, rather than in individual power receptacles scattered around the room. The single enclosure places the receptacles at the point of usage and provides a lower resistance ground path between electrical appliances. Standard straight blade receptacles, NEMA Configuration #5-20R, are now acceptable in operating rooms.

A clock and elapsed-time indicator are required for most operating rooms, enabling the surgeon and anesthetist to easily see clock time and elapsed time. It also gives the support team easy access to the controls. Mount the control panel for the timer at the five foot level with the timer mounted at the seven foot level. Some OR teams prefer to place the control panel within reach of the anesthetist.

Locate the film illuminator directly behind the surgeon for easy accessibility. Place the X-ray receptacle remote indicator behind the support team. If the optional remote power and ground module is used, locate it at the far end of the room; its primary purpose is to supply power for standby equipment such as blood warmers and sterilizers. Figure 7 illustrates the size of power and ground conductors and their correct routing in a typical operating room.

Conductive flooring is still required by code in all flammable and mixed facilities. Conductive flooring is not required for rooms that are designed as nonflammable anesthetizing areas.

It is convenient to have several separate physical points of grounding connected to one electrical point. To do this, designate a central reference ground point, most often located in the isolation panel. For all practical purposes, all ground points in the room are at the same electrical potential. Figure 8 shows a typical operating room grounding system. The ground modules in the operating room contain a highly conductive bus bar equipped with a suitable number of lugs to be used for permanent terminations.

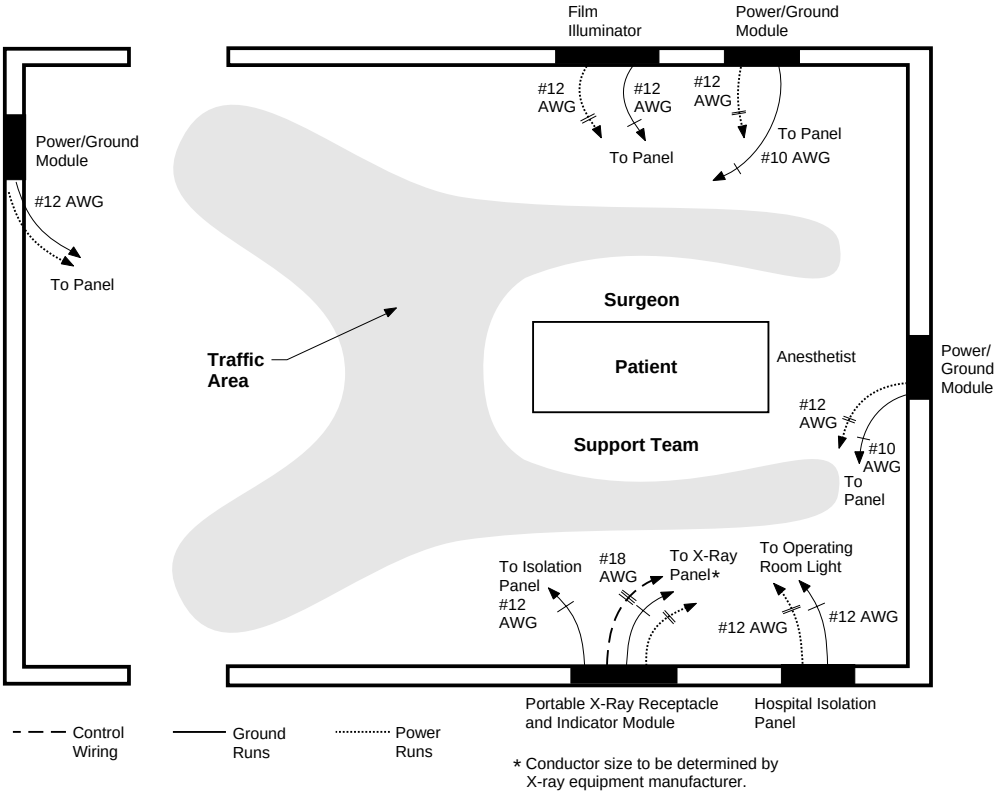

Figure 7

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B. Portable X-Ray System

In operating rooms or critical care areas the portable X-ray outlets require 208V or 240V, and will need a separate isolated distribution system (when isolated power is being used in that room). It is a common procedure to use a single isolated system to supply X-ray circuits for as many as eight operating rooms. These circuits interlock so that only a single circuit can be energized at a given time. The practice has been feasible because few hospitals have more than one portable X-ray machine, and when a hospital has multiple units, it is likely that only one unit will be used at a time.

The circuit is selected at a push-button station in the panel. An “all off” mode is provided. The isolating transformer, circuit breakers, LIM, and control equipment are all mounted in an attractive flush-mounted enclosure.

When the Square D X-ray panel is used, locate it as centrally as possible in the area it will serve. Lay out circuit feeders for minimum length, as in the case of operating room 120V circuits.

The system provides for a remote indicator alarm at each circuit outlet. The only indicator alarm which is operating is the one on the energized circuit. A green light on the remote indicator illuminates, telling operating room personnel that the circuit is energized and safe to use. Another advantage to wiring remote indicator alarms is that, if a fault occurs, the only alarm that sounds will be in the operating room with the energized circuit.

Be careful when connecting the ground terminal of the X-ray receptacle to the grounding system; the ground terminal must connect to the ground system serving the patient who is served by the X-ray receptacle. Connect the ground terminal of the LIM, which monitors the X-ray panel, to the equipment ground bus in the emergency distribution panel serving the 120V isolated systems within these areas. In addition, connect a #12 AWG ground wire between the X-ray panel and the X-ray receptacle.

C. Interlocking Methods

There have been several different methods of controlling the interlocking system for X-ray receptacles. The method to be used is a matter of personal choice. Discuss the methods with the electrical consultant, hospital administration, and hospital radiology staff. Make the final selection after weighing the pros and cons of each method.

At Square D, we have found that the most generally acceptable method is the one just discussed — a series of selector push-buttons, located in the panel, which control the receptacle energizing mode. If the panel is not accessible, the push-button station can be in a separate module, built in a convenient location or added to the operating room nurse’s console.

An on/off switch at each receptacle can provide the selection mode. Energizing this switch would automatically lock out all other receptacles. At first glance, this system appears logical; it lets the X-ray technician control the circuit at the X-ray location. However, this method has not worked well in practice. If a circuit is not shut off after it is used, other circuits remain locked out. If a technician cannot get power to a circuit, he may have to search several other rooms to find the receptacle that was left in the on position.

Generally, operating rooms are connected to the nurse’s station through an intercom, or are located close enough so direct verbal communication is possible. This allows the radiologist to ask the operating suite nurse to energize the circuit in a particular room.

Square D supplies a variety of interlocking type panels and schemes; do not hesitate to ask Square D for the special system that your hospital requires.

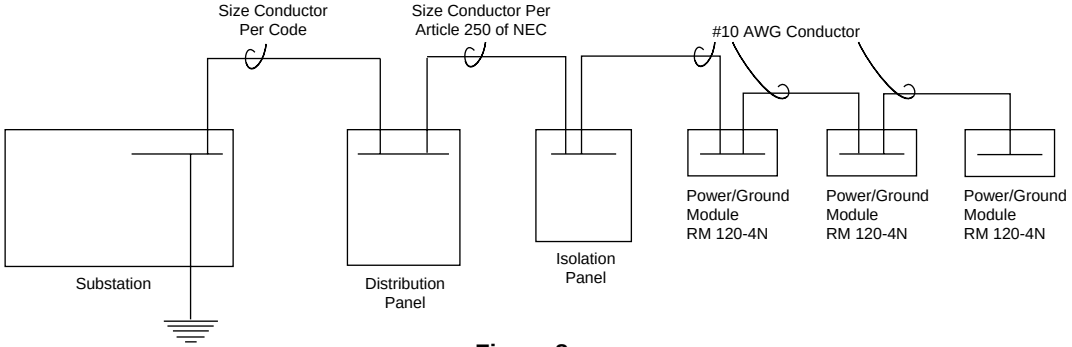

Figure 8

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D. Surgical Facility Panels (SFP)

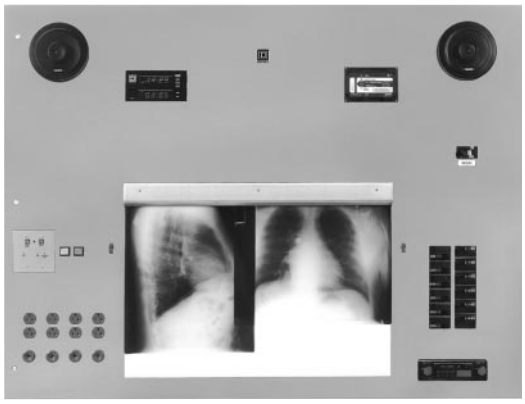
The surgical facility panel offers another method of providing isolated power in an operating room. This large panel condenses many of the electrical accessories normally found in an operating room into one unit.

Components normally included in the surgical facility panel are:

- Isolation transformer
- Surgical clocks and timers
- Line isolation monitor (LIM)
- AM/FM, CD stereo system
- Audible indicator alarm
- Ground jacks
- Circuit breaker panel
- Double-size film illuminators
- Ground bus
- X-ray receptacles
- Power receptacles
- AM/FM cassette stereo system

Because all of these components are in the same panel, location of this panel within the operating room is critical. When specifying a surgical facility panel, consider which location is best for all concerned personnel.

Surgical facility panels are custom designed and assembled; this allows each hospital to specify the individual components that are needed in that hospital.



Typical Surgical Facility Panel

V. Field Test and Inspection

Because of the complexity of isolated power and the ground system, the manufacturer should field test the system before use. This is the only way to ensure that the system is properly installed. The services of a factory technician are available from Square D. The factory trained technician performs the following on-site testing:

- All tests on the isolated system, ground network, and LIM are in accordance with Article 517 of the National Electrical Code and with NFPA No. 99.
- The ground test for power and ground receptacles is performed by applying a constant current between the room reference grounding bus and each ground contact of each receptacle, measuring the resulting voltage. The calculated resistance should be below 0.1Ω. The potential difference between exposed conductive surfaces in the patient vicinity is checked; the difference cannot exceed 20mV across a 1000Ω resistor under normal operation.
- The LIM is tested as installed in the complete isolated system. Combinations of resistive and capacitive faults are placed on the isolated power system. The proper response of the line isolation monitor and its associated alarm device(s) is observed. Corrective steps are taken if improper operation is observed. The completed system is retested to ensure proper operation.
- The impedance of the isolated system (impedance to ground of either conductor) is tested. Impedance must exceed 200,000Ω to conform with NFPA No. 99. The entire installation of the isolated equipment is inspected for conformance with applicable codes to ensure that no code is violated.
- The technician gives a log book to the hospital staff. The staff uses the book to record maintenance and periodic test data. The technician provides orientation to the system, and its maintenance and testing. During this orientation, the technician will answer any questions the hospital staff has about the system. At a later date, the hospital receives a letter containing the test results.

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ELECTRICAL MAINTENANCE

⚠ DANGER

HAZARD OF ELECTRIC SHOCK, BURN, OR EXPLOSION.

- Use extreme caution, some of the following procedures are performed when circuits are energized.
- Only trained personnel should perform these procedures.
- Use electrically insulated tools.

Failure to observe these instructions will result in death or serious injury.

A periodic maintenance program is essential to the safety of hospital patients and personnel. The services of a factory technician are available from Square D. Following a rigid maintenance program can reduce electrical hazards significantly.

Because of the size of hospital electrical systems, it is difficult to establish and follow a maintenance program that includes the entire hospital. However, checking anesthetizing and critical care areas more frequently than general patient areas is recommended.

Isolated Power System

Before using an isolated power system, certain tests should be conducted to verify proper installation of the equipment and wiring. To conduct these tests, disconnect all secondary equipment from the secondary circuits. Conduct these tests before patient occupation. Follow the test procedures listed below:

LIM Test

1. Energize the isolation panel by closing the primary circuit breaker. Leave the secondary circuit breakers in the off position. Verify that the LIM is operating. You should observe a slight meter deflection, indicating the monitor hazard current plus the hazard current for the isolation panel.
2. Press the push-to-test button on the LIM to ensure its test capability. Also check for audible and visible alarms attached to the LIM. The alarms should operate in the safe condition and in the alarm condition. Ensure that the alarm will silence when the silence button is pressed.
3. Record the hazard current reading for the LIM with only the primary circuit breaker closed. Then close one secondary circuit breaker at a time, recording the hazard current reading for that circuit only. Close only one circuit breaker at a time; otherwise, the reading cannot be attributed to a specific circuit. If any circuit shows an unusually high hazard current compared to other circuits, investigate it immediately.
4. Determine the line-to-ground impedance between each of the power conductors and ground. Conduct this test at any of the receptacles; be sure that all the secondary breakers are in the “on” position. Disconnect the LIM from the circuit during this test. To conduct this test, place a 0–1 milliammeter between either line to ground and measure the current. The value of current divided into the system voltage determines the system impedance. This impedance must be greater than 200 kilohm (kΩ) for either line to ground. For a 120V system, this compares to 600µA. Conduct this system impedance test without any secondary equipment connected to the circuits. If the impedance is less than that required by NFPA No. 99, investigate the system and correct the problem.
5. Test the LIM to ensure the proper alarm trip point. To perform this test, place a value of resistance between one line and ground to act as the fault impedance. The fault impedance should be inserted directly into the LIM with all secondary wiring disconnected. Use the following equation for fault impedance:

E = System Voltage

R = Fault Impedance in Ohms

I = Alarm Trip Current-Monitor Hazard Current at Trip Point in Amperes

$$R = \frac{E}{I}$$

For a capacitive fault, use the following equation:

E = System Voltage

R = Fault Impedance as Calculated Above in Ohms

C = Capacitance in Farads

$$C = \frac{1}{0.377R}$$

The LIM should alarm for an impedance of 10% of this value; if it does not alarm, contact the manufacturer.

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NFPA No. 99 recommends that the following formula be used to fault the LIM:

R = 200 X System Voltage

e.g., If a system measures 120V, the fault impedance would be:

R = 200 X 120

= 24 K ohms

Ground Test

6. For proper continuity, test the ground system associated with the isolated power system before its initial use. To perform the test, inject 20A between the ground bus in the isolation panel and the grounded points on receptacles and ground jacks. The potential difference measured between these two points should not exceed 2V. If it does exceed 2V, inspect the ground for proper connection and properly sized wire. The 20A ground test can also verify that all metal within the room is properly grounded. To perform this test, attach probes between metal surfaces and the room ground bus; verify the ground connection. This test can also be conducted with an 0–0.1 ohm meter.
7. Perform periodic testing, according to this schedule:

- Test the LIM push-to-test button monthly. Check the associated alarms and silence functions.
- Calculate an external fault impedance once every six months. At this time, take LIM readings with all circuit breakers closed and with all circuit breakers open. This provides a running history for the permanently installed wired system. If these values significantly increase, inspect the system and take corrective action.

Adapters and Extension Cords

The use of extension cords in patient areas and anesthetizing locations often presents an electrical hazard. Although extension cords offer flexibility, they are often abused. These cords may lie in traffic areas where people step on them and roll equipment over them. They may also lie in pools of fluid. It is safer to install a sufficient number of accessible receptacles than to use extension cords.

Medical Equipment Maintenance

The increased use of biomedical instruments presents another maintenance responsibility. Hospitals should establish routine programs to test and maintain such equipment.

The maintenance program should apply to all patient care areas; but it is of greatest importance for special care units where the most seriously ill patients and the most complex equipment co-exist. The amount of equipment present varies by hospital, affecting the complexity of the program. However, the following items should be found in every medical equipment testing program:

- An established procedure ensuring that equipment serves the purpose for which it is intended; that it is safe, reliable, and the best choice for its purpose
- Specifications that must be adhered to by manufacturers before lease/purchase of equipment
- Adequate customer support from the manufacturer, ensuring technical assistance, repair, and consultation as needed
- Periodic inspections, calibration, and preventive maintenance
- Immediate, thorough inspections when equipment malfunction or shock is considered a possibility
- Close monitoring of services provided by outside vendors
- A logging/reporting system that provides effective control and record keeping
- In-service training to ensure safe, effective use of medical equipment

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Testing Personnel. Hospitals may choose to employ their own medical engineering personnel, share this personnel with other hospitals, or contract with an outside vendor to service medical equipment. Each hospital must choose the best option for its purposes.

The size of the hospital, presence of other hospitals in the area, and regional demographics will help each hospital make the appropriate decisions about testing personnel.

Leakage Current. All portable equipment has the potential for leakage current. Periodically test these pieces of equipment and tag the equipment, showing leakage current readings. Equipment that connects directly to patients should have its patient leads checked for leakage current. Each hospital should maintain the necessary testing equipment to conduct these testing procedures.

Testing Programs. Planning and implementing a medical equipment control program should include the following factors:

- The hospital should obtain competent, objective biomedical engineering assistants when planning and developing the program.
- A committee must be formed, which meets for the sole purpose of medical equipment control.
- All medical equipment must be defined and inventoried.
- The hospital should appraise several options for its equipment control, rather than choose the easiest or most available program.
- The appropriate medical engineering services must be obtained.
- The necessary test equipment must be leased/purchased, and be kept on site.
- The hospital must develop procedures, specifications, and additional program components to meet its needs.

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Electrical equipment should be serviced only by qualified electrical maintenance personnel, and this document should not be viewed as sufficient instruction for those who are not otherwise qualified to operate, service or maintina the equipment discussed. Although reasonable care has been taken to provide accurate and authoritative information in this document, no responsibility is assumed by Square D for any consequences arising out of this material.

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